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Fig. 4. Pipes in place. Note buttresses between pipes to aid in passing debris.

think. The actual cost of construction was much under the estimate, judging from the bids received. I have no actual cost data. I have always felt that this was a private matter with a contractor and made no attempt to get this information.

Do not get the impression that we are recommending this type of construction for general use. I do, however, think that there are many places for its use, especially in level territory where the water, during flood periods, spreads out over large areas where, in order to accommodate all-year traffic, long and high fills would have to be built for approaches. A further determining factor is that most of the county roads now being built are light-traffic roads, connecting in most cases heavier-traffic roads. Even though for 5 or 10 days during the year traffic desiring to use the road would be forced to detour, the saving in original cost of 50% justifies this type of construction. At least, it has met with universal approval wherever we have used it in our country.

DESIGN AND CONSTRUCTION OF CONCRETE CULVERTS

By J. W. Botset, Marshall County Surveyor

In designing a culvert, one of the first things to determine is just what kind of structure is needed for the particular situation. It seldom happens that the same design of structure will fit two locations. For instance, the stream may cross at an angle with the center line of the roadway, necessitating a skewed culvert, or special wing walls or retaining

walls may be needed. When you go before the county council to ask for the appropriation, usually their first question is, "How much is it going to cost?" Therefore, the cost should be watched closely. A high-priced bridge should not be designed on a second- or third-class road, but rather a structure which will answer the purpose but not sacrifice safety and endurance to economy. It is essential that the proper waterway area be determined for the structure, but I shall not go into that for if you will turn to your copy of last year's Road School proceedings, you will find Prof. G. P. Springer's paper on "Waterways for Culverts and Bridges" in which he goes into this matter in detail.

One of the most important things in designing a bridge is to establish the flow line and grade of the roadbed in proper relationship. Note if the ditch is in need of cleaning and, if so, an investigation should be made to find out how much deeper it will probably go in order to give proper drainage after cleaning. Then design your footings and abutments for this new grade. This may not appeal to some of the taxpayers, but if they see some of the older structures undermined and possibly collapsing during recleaning, they will change their minds. Many good structures have been lost by not carrying the footing down to a proper depth.

TYPE OF BRIDGES AND CULVERTS

We have ceased building plank-floored bridges and are now building all concrete structures. On structures where a 10-foot waterway or less is needed, we are using box culverts under fill, with a roadway width of less than 26 feet. On structures with a waterway over 10 feet and less than 20 feet, we have been using the reinforced slab top with the proper abutments and wing walls. On structures of 20 feet and over, either I-beams with concrete floor or reinforced concrete girders are used. The box culvert type can be built with or without handrails. On spans of 10 feet and over, I think the concrete hand rail with bush-hammered panels makes a neat job if rubbed to a smooth surface.

Alignment, sight distance, guard rail approaches, approach grades, etc., are very important points to be watched. Bridges and culverts should be designed to carry a load of not less than a 20-ton roller, with a clear roadway of not less than 20 feet. On our heavier traveled roads, we are building 24-foot roadways.

A great help to county engineers in designing bridges and culverts are the standard plans provided by the state highway commission for their different size bridges and culverts.

CONSTRUCTION

Personally, I get more pleasure out of construction of bridges than almost any work connected with the office, and I will try to give you some of our methods. The first essential

of good construction is a set of plans and specifications which covers every phase of the construction clearly, giving proper dimensions and showing different parts in detail.

After the contract is let and the contractor is ready to go to work, I always aim to get to the bridge site and locate the structure from previous references. The center line of the road and stream line should be staked with extreme care. I find the best practice is to put in a number of heavy, permanent stakes so that lines may be stretched from stake to stake for the center line of the bridge, outside lines of structure, and face lines of abutments or footings. Then there is no excuse for improper excavating.

The footing excavation should be large enough so that after the sheet piling is driven there will still be proper clearance for the footing dimensions. Don't let the contractor kid you into the idea that the banks of the cut will stand without sheeting. About nine times out of ten they will not and then the engineer and contractor will both have plenty of trouble. We have built thirty-two structures in the last two and one-half years, and out of this number I think there were not over four or five which did not require sheeting. It is always better to play safe and have the contractor make arrangements for sheet piling.

Always urge the contractor to use nothing less than 1½ inch lumber for small excavations and 2-inch for larger excavations. Another mistake many contractors make is in not using heavy enough timbers for whaling members and struts. I have seen several excavations lost by this error. Another precaution is to compel the contractor to use straight lumber for his sheeting, for in this way he will be able to get a uniformly tight cofferdam and keep the water level at a safe elevation. The engineer will then have a chance to see that all is well in the bottom of the excavation before placing the concrete.

In placing sheet piling, if there is any danger of having much water, it is well to have the contractor build a box at one end of the excavation down below the bottom of the excavation which will serve as a sump. Then, with the proper sized pumps, he will always be able to keep the water down to a proper level where it will not interfere.

We have found that it is best to start pouring the footing at one end of the excavation and to use false stops or partitions which are moved alternately by stages to the other side after concrete has been poured up part way in each section. In this way the water can be kept down better.

Good straight lumber should be used for forms, with plenty of studding in order to prevent springing or bulging. It is good practice, after building up the forms and before wiring, to cut about three sets of spreaders to the right length for the different heights, using one set at the bottom, one about half way up, and one at the top. Leave these spreaders in

place until the wires are all placed and drawn taut, then line up the form and, with bracing from outside, you will eliminate bad bulges.

Weep holes should be placed in abutment walls. A piece of 4-inch pipe is satisfactory. These pipes are placed in the forms and securely wired with the proper slope. The weep holes should be placed near the bottom, but not too low to prevent good drainage.

In building slab top bridges and culverts, adequate, substantial false-work should be provided. It is better to have an extra row of posts than to experience settlement after the load has been applied.

In our plans, we always indicate how reinforcing steel should be cut and bent. Great care should be taken by the contractor to get steel in its correct location, with proper lap, and wired securely to avoid displacement when the concrete is poured.

Fig. 1. A typical small concrete bridge constructed in Marshall County.

Only clean, washed gravel and sand should be used as aggregate at any time. Don't let some contractor tell you that Jones has a good deposit of pit-run gravel perfectly all right for this work. He will tell you that Smith has built a concrete silo or a barn wall using this gravel, years ago, and, that the concrete is still in good shape. But be firm in your decision and thus insure good concrete if other parts of the specifications are fulfilled.

For coarse aggregate we have been using stone from 2 inches to 8 inches, and a good sharp sand for fine aggregate. We use a 1:2:3 mix with a 3- to 4-inch slump with good results.

All portions of a structure exposed to the earth backfill should have a coating of asphalt or other good waterproofing material before backfilling is done. Outside surfaces should be rubbed with carborundum brick until all form marks have been eliminated and a smooth surface has been secured. Panels should be bushhammered. (Fig. 1.)

INSPECTION

Until about a year and a half ago, when we had serious inspection troubles, the county commissioners always appointed some farmer as inspector. This appointee seldom knew what a set of plans was for except to carry around in his pocket to make it look as if he were doing a good job. Since that time the commissioners have listened to me and have appointed no more farmers, but have turned all inspection over to our office. Either I or my deputy has full charge of inspection and in this way have been able to save the taxpayers quite a sum of money. We kept a close check on eight structures and, in comparison with former inspection methods, we saved a little over $500 for the taxpayers. We do not spend any more time on structures than is necessary. First we stake it out and get the contractor started, then leave orders that as soon as he thinks he has his excavation ready to let us know. We then go out and check the work and if we find the excavation ready for pouring, one of us stays on the job until the concrete is poured. We then go about our other work until he has his forms ready to check when we do the same as before.

IMPORTANT FEATURES OF CONCRETE HIGHWAY SPECIFICATIONS

By Emil Zabel, Jackson County Surveyor

It is generally conceded that the first concrete pavement in the United States was laid in Bellefontaine, Ohio, in the year 1893. Very little headway was made in this type of pavement for rural road purposes until the year 1910. As the number of motor vehicles increased, however, the demand for more pavements increased, and as a result the modern concrete pavement has come into existence. In the evolution of the old concrete slab to the pavement as we know it today, many changes have been made in the specifications. It is well to bear in mind that the making of concrete is still in its infancy and that in the years to come there will be further changes in the specifications governing its production. In the following remarks the Indiana State Highway specifications will be followed closely as a standard. In writing up specifications for a one-course, plain portland cement concrete pavement, there are, of course, several important items to be covered.

SUBGRADE

The important thing to keep continually in mind about the subgrade is that it must support the slab *uniformly*. Concrete roads crossing swamps have surprised observers by the ab-